

APPLICATION FOR UNITED STATES PATENT

HIGH VISCOSITY INDEX WIDE-TEMPERATURE FUNCTIONAL FLUID
COMPOSITIONS AND METHODS FOR THEIR MAKING AND USE

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PATENT TRADEMARK OFFICE

HIGH VISCOSITY INDEX WIDE-TEMPERATURE FUNCTIONAL FLUID
COMPOSITIONS AND METHODS FOR THEIR MAKING AND USE.

5 [0001] This application claims the benefit of U.S. Provisional Application No. 60/432,591 filed December 11, 2002.

FIELD OF THE INVENTION

10 [0002] The present invention relates to novel high viscosity index, low-viscosity lubricants usable as wide-temperature hydraulic oils comprising novel low-viscosity base stocks, with improved performance in low-temperature viscosity, and the methods to produce them. The novel base stocks and base oils incorporated into this invention exhibit an unexpected combination of high 15 viscosity index (130 or greater) and a ratio of measured-to-theoretical high-shear/low-temperature viscosity at -30C or lower and the methods of making them.

BACKGROUND OF THE INVENTION

20 [0003] Hydraulic equipment owners require their equipment to operate effectively over a wide temperature range. For example, cargo handling hydraulic systems aboard cargo ships must be able to operate regardless of the prevailing climate, which can range from tropical to arctic conditions.

25 [0003] Consequently, hydraulic oils have been developed which have good low-temperature flow properties for service under severe cold climatic conditions, and which provide good high-temperature performance for hot climatic conditions.

In order to achieve the desired wide temperature working range, hydraulic oils are commonly formulated in two ways. The first standard formulation technique involves using mixtures of solvent-refined paraffinic base oil(s) and solvent-refined naphthenic base oil(s), with added shear stable viscosity modifier and pour point depressant. The second standard formulation technique involves using polyalpha olefin base oil (PAO, Group IV base stock).

[0004] The first technique requires a more complex formulation approach but is generally preferred because it is more cost-effective than the second technique which requires an expensive, special base stock such as PAO. Also, the use of solvent-refined naphthenic base oil is often required to improve the low-temperature viscosity of the solvent-refined paraffinic base oils used in the mineral oil mixture recited in Option (1).

[0005] A usable wide-temperature hydraulic oil generally meets the following laboratory bench test performance levels in order to meet the service expectations of hydraulic equipment users:

- (a) viscosity index of about 135-140, preferably 140 or higher, as measured by ASTM D2270 test.
 - (b) pour point of about -35C to -40C, preferably -40C or lower, as measured by ASTM D97 test.
 - (c) Brookfield viscosity at -20F of about 6500 cP or lower, preferably 6200 cP or lower, as measured by ASTM D2983 test.
- As an alternative to traditional Group I mineral oils and to special PAO base oils, high viscosity index Group III base oils would be expected to be usable in a wide-temperature hydraulic oil application. Group III base stock may be used without added solvent-refined naphthenic base stock, but generally continues to be formulated with viscosity modifier and pour point depressant.

[0006] Tests used in describing lubricant compositions of this invention are:

- (a) CCS viscosity measured by Cold Cranking Simulator Test (ASTM D5293);
- 5 (b) Noack volatility (or evaporative loss) measured by CEC-L-40-A-93;
- (c) Viscosity index (VI) measured by ASTM D2270;
- (d) Theoretical viscosity calculated by Walther-MacCaull equation (ASTM D341 appendix 1);
- 10 (e) Kinematic viscosity measured by ASTM D445
- (f) Pour point as measured by ASTM D5950.
- (g) Scanning Brookfield Viscosity as measured by ASTM D5133
- (h) Brookfield Viscosity as measured by ASTM D2983.
- (i) ISO viscosity as defined by the viscosity grade classification in
- 15 ISO 3448.

[0007] The inventors note that the Walther-MacCaull equation of ASTM D341 computes a theoretic kinematic viscosity, while the CCS reports an absolute viscosity. To compute the ratio as used herein, the inventors converted
20 the Walther-MacCaull viscosity as per equation (I).

$$(I) \quad \text{Theoretical viscosity @ } T_1(\text{°C}) = \text{Walther-MacCaull Calculated Kinematic Viscosity @ } T_1(\text{°C}) \times \text{Density at } T_1 (\text{°C})$$

where T_1 is the desired temperature.

- 25 The density at -35°C is estimated from the density at 20°C using well-known formula. See, e.g., A. Bondi, "Physical Chemistry of Lubricating Oils", 1951, p. 5.

[0008] A base stock (as opposed to a base oil and a lubricant composition) is defined as a hydrocarbon stream produced by a single manufacturer to the same specifications (independent of feed source or manufacturers location) and that is identified by a unique formula, product identification number, or both.

5 Base stocks may be manufactured using a variety of different processes including but not limited to distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. Rerefined stock shall be substantially free from materials introduced through manufacturing, contamination or previous use. A base stock slate is a product line of base
10 stocks that have different viscosities but are in the same base stock grouping and from the same manufacturer. A base oil is the base stock or blend of base stocks used in formulated lubricant compositions. A lubricant composition may be a base stock, a base oil, either alone or mixed with other stocks, oils or functional additives.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 graphically compares the measured CCS viscosities against the predicted Walther-MacCoull viscosities at various temperatures.

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[0010] Figure 2 graphically illustrates the viscosity versus Noack volatility profiles for various oils.

[0011] Figure 3 graphically compares the kinematic viscosity versus CCS viscosity for various inventive oils and comparative examples.

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SUMMARY OF THE INVENTION

[0012] This invention relates to functional fluids which incorporate base stocks and base oils that achieve improved viscosity performance at low temperatures (about -25C or lower). The present invention also relates to functional fluids which comprise a base oil derived from waxy hydrocarbon feedstocks, either from natural or, mineral, or synthetic sources (e.g. Fischer-Tropsch-type processes). This invention also relates to processes or methods to make such functional fluids.

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[0013] More specifically, this invention relates to functional fluids having an unexpectedly advantageous wide-temperature viscosity profile and comprising novel base stocks and base oils with improved low-temperature fluidity (as described by a ratio of measured-to-theoretical high-shear/low-temperature viscosity at -30C or lower). In addition, this invention relates to functional fluids that are surprisingly useful as hydraulic oils having improved low-temperature viscosity as measured by Brookfield viscosity at -20F or lower. The beneficial characteristics of good low-temperature fluidity uniquely differentiate the base stocks and base oils incorporated into this invention from other similar Group III base oils, and further differentiate the lubricant compositions and functional fluids of this invention from other Group III-based compositions.

[0014] More specifically, this invention encompasses a functional fluid which incorporates base stocks that have the surprising and unexpected simultaneous combination of properties of:

- (a) viscosity index (VI) of 130 or greater,
- (b) a pour point of -10C or lower,
- (c) a ratio of measured-to-theoretical low-temperature viscosity equal to 1.2 or less, at a temperature of -30C or lower, where the measured

viscosity is cold-crank simulator viscosity and where theoretical viscosity is calculated at the same temperature using the Walther-MacCoul equation.

5 [0015] The base oil compositions incorporated into this invention encompass not only individual base stocks as manufactured, but also mixtures or blends of two or more base stocks and/or base oils such that the resulting mixture or blend satisfies the base stock requirements of this invention. The base oil compositions of this invention encompass a range of useful viscosities, with base
10 oil kinematic viscosity at 100C of about 1.5 cSt to 8.5 cSt, preferably about 2 cSt to 8 cSt, and more preferably about 3 cSt to 7.5 cSt. The base oils of this invention encompasses a range of useful pour points, with pour points of about -10C to greater than -30C, preferably about -12C to greater than -30C, and more preferably about -14C to greater than -30C. In some instances, the pour point
15 may range from -18C to -30C and may further range from -20C to -30C.

[0016] Preferably, the base stocks and base oils incorporated into this invention as used herein will have a measured-to-theoretical low-temperature viscosity of about 0.8 to about 1.2 at a temperature of -30C or lower, where the
20 measured viscosity is cold-crank simulator viscosity and where theoretical viscosity is calculated at the same temperature using the Walther-MacCoul equation

[0017] .Surprisingly the low measured-to-theoretical viscosity ratio, which
25 distinguishes one unexpected performance advantage of the base stocks and base oils of this invention, can also be expected to be observed at temperatures below -35C, for example down to -40C or even lower. Thus at these low temperatures, actual viscosity of novel base stocks and base oils described hereinwould be expected to approach the desired, ideal, theoretical viscosity,

while comparative base stocks and base oils would be expected to deviate even more strongly away from theoretical viscosity (i.e. to higher measured-to-theoretical viscosity ratios).

- 5 [0018] Additionally, the novel base stocks and base oils incorporated into this invention may have the following properties:
 - (a) saturates content of at least 90wt%, and
 - (b) a sulfur content of 0.03 wt.% or less
- 10 [0019] Viscosity index of the novel base stocks and base oils incorporated into this invention may be 130 or greater, or preferably 135 or greater and in some instances, 140 or greater. The desired pour point of the novel base stocks and base oils incorporated into this invention is about -10C or lower, or preferably -12C or lower, or in some instances more preferably -14C or lower.
- 15 In some instances the pour point may be -18 or lower and more preferably, -20C and lower. For the novel base stocks and base oils incorporated into this invention, the desired measured-to-theoretical ratio of low-temperature cold cranking simulator (CCS) viscosity equals about 1.2 or less, or preferably about 1.16 or less, or more preferably about 1.12 or less. For the low-temperature viscosity profiles of the novel base stocks and base oils incorporated into this invention, the desired novel base stocks and base oils incorporated into this invention have CCS viscosity @-35C of less than 5500 cP, or preferably less than 5200 cP, or in some instances more preferably less than 5000 cP.
- 20 [0020] The novel base stocks and base oils described herein may be used with other lubricant base stocks and base oils or co-base stocks and co-base oils in formulated lubricant compositions or functional fluids. In some instances, the highly advantageous low-temperature (-30C or lower) properties of these novel base stocks and base oils incorporated into this invention can beneficially

improve the performance of lubricants and lubricant compositions or functional fluids at concentrations of 20wt% or greater of the total base stocks and base oils contained in such compositions. Preferably, the novel base stocks and base oils incorporated into this invention may be used in combination with other 5 individual base stocks and base oils to gain significant low-temperature performance benefits in finished lubricant compositions or functional fluids. More preferably, the base stocks and base oils may be used at 40wt% or more of the total base stocks and base oils contained in formulated lubricant compositions or functional fluids, without detracting from the elements of this 10 invention. And in certain instances, the base oil(s) may be most preferably used at 50wt% or more of the total base stocks and base oils, or even 70wt% or more of the total base stocks and base oils in finished lubricant compositions or functional fluids.

15 [0021] The novel base stocks and base oils incorporated into the present invention may be produced by:

- (a) hydrotreating a feedstock having a wax content of at least about 50 wt.%, based on feedstock, with a hydrotreating catalyst under effective hydrotreating conditions such that less than 5 wt.% of the 20 feedstock is converted to 650F (343C) minus products to produce a hydrotreated feedstock whose VI increase is less than 4 greater than the VI of the feedstock;
- (b) stripping or distilling the hydrotreated feedstock to separate gaseous from liquid product; and
- 25 (c) hydrodewaxing the liquid product with a dewaxing catalyst which is at least one of ZSM-22, ZSM-23, ZSM-35, ZSM-48, ZSM-57, ferrierite, ECR-42, ITQ-13, MCM-68, MCM-71, beta, fluorided alumina, silica-alumina or fluorided silica alumina under catalytically

effective hydrodewaxing conditions wherein the dewaxing catalyst contains at least one Group 9 or Group 10 noble metal, and

- (d) optionally, hydrofinishing the product from step (c) with a mesoporous hydrofinishing catalyst from the M41S family under hydrofinishing conditions.

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[0022] Another embodiment of this invention relates to a method of making lubricants and lubricant compositions or functional fluids that comprise novel base stocks and base oils incorporated into this invention that have significant 10 performance benefits in reduced low-temperature viscosity, for example in hydraulic oils.

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DETAILED DESCRIPTION OF THE INVENTION

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[0023] This invention relates to novel lubricants and lubricant compositions comprising novel base stocks and base oils, and to methods for optimizing lubrication performance under both low-temperature and high-temperature conditions. The lubricant compositions of this invention comprise base stocks and base oils having an unexpectedly advantageous combination of high 20 viscosity index, and good low-temperature fluidity (as described by low-temperature Brookfield viscosity). These lubricant compositions are found to be useful as hydraulic oils and have surprisingly advantageous combination of performance under both wide temperature conditions, i.e. low-temperature and high-temperature conditions.

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[0024] Surprisingly, lubricants comprising base stocks of this invention were found to demonstrate superior low-temperature viscosity performance as measured by Brookfield viscosity at -20F or lower. In addition, inventive functional fluids comprising exclusively the novel inventive base stocks recited

herein unexpectedly achieve superior Brookfield viscosity performance results with no added viscosity modifier. This represents and unexpected and novel alternative solution to the problem of balancing good low-temperature viscosity with good high-temperature viscosity in wide-temperature applications, such as,
5 for example wide-temperature hydraulic oils.

[0025] In addition, improvements in Brookfield viscosity performance are demonstrated by the inventive functional fluids recited herein even in cases where a more traditional formulation strategy is used, i.e. combining lower
10 viscosity base stocks or base oils with a viscosity modifier. For example, in hydraulic oil compositions comprising the novel base stocks and base oils described herein, improved Brookfield viscosity at -20F or lower was found, and was significantly better than the Brookfield viscosity of compositions formulated with currently available Group III base stocks.

15 [0026] Functional fluids comprising the novel base stocks and base oils described herein may be formulated to obtain finished lubricant products having a range of useful ISO viscosity grades (according to ISO 3448), from about ISO 2 to about ISO 1500. Specifically, hydraulic oil compositions comprising these
20 novel base stocks and base oils incorporated into this invention may have useful ISO viscosity grades of from about ISO 10 to ISO 150, preferably from about ISO 15 to ISO 100, more preferably from about ISO 22 to ISO 100, and in some instances most preferably ISO 32 to ISO 68.

25 [0027] The inventive functional fluids comprising the novel base stocks and base oils described herein have unexpectedly good low-temperature viscosity as measured by the Brookfield viscosity test (ASTM D2983). This result is unanticipated because the CCS viscosities used in describing the novel base stocks of this invention are not predictive of Brookfield viscosities found for the

corresponding formulated lubricant compositions. CCS viscosity and Brookfield viscosity are sensitive to different low-temperature base stock performance mechanisms, with CCS viscosity and Brookfield viscosity being determined under differing shear conditions.

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[0028] One embodiment of this invention encompasses novel functional fluids having improved Brookfield viscosity at -20F or lower and that may be advantageously used in wide-temperature lubricant applications, such as, for example hydraulic oils.

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[0029] The high viscosity index base stocks incorporated into this invention have superior low-temperature performance when compared to other high viscosity index base stocks. The difference in performance is most critical in the temperature range below -30C, where conventional high viscosity index Group III base stocks deviate significantly from the theoretical viscosity. To illustrate, measured low-temperature CCS viscosity of comparative conventional high viscosity index Group III base stocks tends to deviate to higher viscosity values than that predicted (Walther-MacCoull equation) for the expected theoretical viscosity of the same base stocks at low temperatures (Figure 1).

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[0030] The novel base stocks and base oils described herein surprisingly demonstrate the more ideal and highly desirable performance predicted by the theoretical viscosity behavior of base stocks and base oils, as described according to the Walther-MacCoull equation (ASTM D341 appendix). In addition, the novel base stocks and base oils incorporated into this invention are found to be surprisingly different from available commercial Group III base oil regarding the ratio of measured-to-theoretical low-temperature viscosity, where actual viscosity is measured as cold cranking simulator (CCS) viscosity at temperatures of -30C or lower, and where theoretical viscosity derives from the

Walther-MacCoull equation (ASTM D341, appendix) at the same temperature as the measured CCS viscosity. It has similarly been observed that these novel base stocks have a much lower scanning-Brookfield viscosity (ASTM D5133) values at low temperature (below -20C). CCS viscosity is measured under high sheer conditions, whereas scanning Brookfield viscosity is measured under low sheer conditions.

[0031] The novel base stocks and base oils described herein have the unique and highly desirable characteristic of a measured-to-theoretical viscosity ratio of 10 1.2 or lower, preferably 1.16 or lower, and in many instances more preferably 1.12 or lower. Base stocks and base oils having measured-to-theoretical viscosity ratios of less than about 1.2 and with ratios approaching 1.0 are highly desirable, because lower ratios indicate significant advantages in low-temperature performance and operability. The currently available Group III base 15 stocks and base oils, however, have characteristic measured-to-theoretical viscosity ratios of 1.2 and higher, indicating poorer base oil low-temperature viscosity and operability. In some instances, it is preferred to have the measured-to-theoretical viscosity ratio be between about 0.8 and about 1.2.

[0032] In one embodiment of this invention, the novel base stocks and base oils incorporated into this invention have the surprising and unexpected simultaneous combination of properties of:

- (a) viscosity index (VI) of 130 or greater,
- (b) a pour point of -10C or lower,
- 25 (c) a ratio of measured-to-theoretical low-temperature viscosity equal to 1.2 or less, at a temperature of -30C or lower, where the measured viscosity is cold-crank simulator viscosity and where theoretical viscosity is calculated at the same temperature using the Walther-MacCoull equation.

[0033] Additionally, the novel base stocks and base oils described herein may also have the following properties:

- (a) saturates content of at least 90wt%, and
- 5 (b) a sulfur content of 0.03 wt.% or less.

As used herein, the term lubricant includes, but is not limited to, lubricant compositions, formulated lubricant compositions, lubes, functional fluids, lube products, lube oils, finished lubes, finished lubricants, lubricating oils, greases and the like.

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[0034] This invention also encompasses functional fluids comprising the inventive base oil compositions with the properties:

- (a) a viscosity index (VI) of 130 or greater,
 - (b) a pour point of -10C or lower,
 - 15 (c) a ratio of measured-to-theoretical low-temperature viscosity equal to 1.2 or less, at a temperature of -30C or lower, where the measured viscosity is cold-crank simulator viscosity and where theoretical viscosity is calculated at the same temperature using the Walther-MacCull equation.
- 20 In some instances, it is preferred to have the measured-to-theoretical viscosity ratio be between about 0.8 and about 1.2.

[0035] One embodiment of this invention encompasses functional fluids having improved Brookfield viscosity at -20F or lower comprising the inventive base stock and at least one performance additive. Another embodiment of this invention encompasses a functional fluid having improved Brookfield viscosity at -20F or lower comprising base stocks of this invention in combination with one or more additional base stocks, and at least one performance additive. A further embodiment of this invention encompasses a functional fluid having

improved Brookfield viscosity at -20F or lower comprising base stocks of this invention without the use of any added viscosity modifier.

5 [0036] Another embodiment of this invention encompasses an hydraulic oil having improved Brookfield viscosity at -20F or lower and comprising the novel base stocks described herein. An additional embodiment of this invention encompasses a method for improving the Brookfield viscosity of functional fluids using the novel base oils recited herein.

10 [0037] Other embodiments of this invention relate to methods of (a) making functional fluids useful as wide-temperature hydraulic oils comprising the novel base stocks recited herein, and (b) making formulated functional fluids comprising the novel base oils recited herein with such compositions or fluids having improved low-temperature Brookfield viscosity at -20F or lower.

15 [0038] Another embodiment encompasses a formulated lubricant composition or functional fluid having improved Brookfield viscosity at -20F or lower comprising the novel base stocks recited herein, with said functional fluids having a viscosity index of about 135 or higher, preferably 140 or higher.

20 [0039] Another embodiment encompasses a functional fluid having improved Brookfield viscosity at -20F or lower comprising the novel base stocks recited herein, functional fluids having a pour point of about -35C or lower, preferably about -40C or lower.

25 [0040] Another embodiment encompasses a formulated lubricant composition or functional fluid having improved Brookfield viscosity at -20F or lower comprising the novel base stocks recited herein, with said lubricant compositions or functional fluids having a Brookfield viscosity at -20F of about 40000cP or

lower, preferably about 28000 cP or lower, more preferably 6500 cP or lower, and even more preferably about 6200 cP or lower.

[0041] Products which incorporate the novel base stocks or base oils recited
5 herein clearly have an advantage over other similar products made from conventional Group III base stocks. One embodiment of this invention is a formulated lubricant composition or functional fluids comprising novel base stocks and base oils described herein in combination with one or more additional co-base stocks and base oils. Another embodiment of this invention is a
10 formulated lubricant composition or functional fluid comprising the novel base stocks and base oils described herein in combination with one or more performance additives.

[0042] Performance additives as used in this invention may encompass, for
15 example, individual additives as components, combinations of one or more individual additives or components as additive systems, combinations of one or more additives with one or more suitable diluent oils as additive concentrates or packages. Additive concentrate encompasses component concentrates as well as additive packages. Often in making or formulating lubricant compositions or
20 functional fluids, viscosity modifiers or viscosity index improvers may be used individually as components or concentrates, independent of the use of other performance additives in the form of components, concentrates, or packages. The amount and type of performance additives that may be combined with the base oils of this invention are limited such that the lubricant composition
25 comprising this total base oil mixture and one or more performance additives simultaneously meet the low-temperature Brookfield viscosity at -20F or lower and high-temperature kinematic viscosity at 40C or above that are useful for wide-temperature hydraulic oils applications.

[0043] This invention is surprisingly advantageous in applications where low-temperature properties are important to the performance of the finished lube or functional fluid. The novel base stocks and base oils described herein may be advantageously used in many of the following applications, for example
5 hydraulic fluids, compressor oils, turbine oils, circulating oils, gear oils, paper machine oils, industrial oils, automotive oils, manual transmission fluids, automatic transmission fluids, drive train fluids, engine oils, gas engine oils, aviation piston oils, diesel oils, marine oils, greases, and the like.

10 **PROCESS**

[0044] The products that derive from the processes of this invention demonstrate not only unique combinations of physical properties, but demonstrate unique compositional properties that distinguish and differentiate
15 them from available commercial products. Thus, the novel base stocks and base oils described hereunderived from the processes recited herein are expected to have unique chemical, compositional, molecular, and structural features that uniquely define the base stocks and base oils of this invention.

20 [0045] The novel base stocks and base oils described hereinare made according to processes comprising the conversion of waxy feedstocks to produce oils of lubricating viscosity having high viscosity indices and produced in high yields. Thus, one may obtain base stocks and base oils or base stocks having
25 VIs of at least 130, preferably at least 135, more preferably at least 140, and having excellent low-temperature properties. Base stocks made according to these processes meet the requirements of a Group III base stock and can be prepared in high yields while at the same time possessing excellent properties such as high VI and low pour point.

[0046] The waxy feedstock used in these processes may derive from natural or mineral or synthetic sources. The feed to this process may have a waxy paraffins content of at least 50% by weight, preferably at least 70% by weight, and more preferably at least 80% by weight. Preferred synthetic waxy feedstocks generally have waxy paraffins content by weight of at least 90wt%, often at least 95wt%, and in some instances at least 97wt%. In addition, the waxy feed stock used in these processes to make the novel base stocks and base oils described hereinmay comprise one or more individual natural, mineral, or synthetic waxy feedstocks, or any mixture thereof.

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[0047] In addition, feedstocks to these processes may be either taken from conventional mineral oils, or synthetic processes. For example, synthetic processes may include GTL (gas-to-liquids) or FT (Fischer-Tropsch) hydrocarbons produced by such processes as the Fischer-Tropsch process or the Kolbel-Englehardt process. Many of the preferred feedstocks are characterized as having predominantly saturated (paraffinic) compositions.

[0048] In more detail, the feedstock used in the process of the invention are wax-containing feeds that boil in the lubricating oil range, typically having a 20 10% distillation point greater than 650F (343C), measured by ASTM D 86 or ASTM 2887, and are derived from mineral or synthetic sources. The wax content of the feedstock is at least about 50 wt.%, based on feedstock and can range up to 100 wt.% wax. The wax content of a feed may be determined by nuclear magnetic resonance spectroscopy (ASTM D5292), by correlative ndM 25 methods (ASTM D3238) or by solvent means (ASTM D3235). The waxy feeds may be derived from a number of sources such as natural or mineral or synthetic. In particular, waxy feeds may include, for example, oils derived from solvent refining processes such as raffinates, partially solvent dewaxed oils, deasphalted oils, distillates, vacuum gas oils, coker gas oils, slack waxes, foots oils and the

- like, and Fischer-Tropsch waxes. Preferred feeds are slack waxes and Fischer-Tropsch waxes. Slack waxes are typically derived from hydrocarbon feeds by solvent or propane dewaxing. Slack waxes contain some residual oil and are typically deoiled. Footh oils are derived from deoiled slack waxes. The Fischer-Tropsch synthetic process prepares Fischer-Tropsch waxes. Non limiting examples of suitable waxy feedstocks include Paraflint 80 (a hydrogenated Fischer-Tropsch wax) and Shell MDS Waxy Raffinate (a hydrogenated and partially isomerized middle distillate synthesis waxy raffinate.)
- 10 [0049] Feedstocks may have high contents of nitrogen- and sulfur-contaminants. Feeds containing up to 0.2 wt.% of nitrogen, based on feed and up to 3.0 wt.% of sulfur can be processed in the present process. Feeds having a high wax content typically have high viscosity indexes of up to 200 or more. Sulfur and nitrogen contents may be measured by standard ASTM methods
15 D5453 and D4629, respectively.
- [0050] For feeds derived from solvent extraction, the high boiling petroleum fractions from atmospheric distillation are sent to a vacuum distillation unit, and the distillation fractions from this unit are solvent extracted. The residue from
20 vacuum distillation may be deasphalting. The solvent extraction process selectively dissolves the aromatic components in an extract phase while leaving the more paraffinic components in a raffinate phase. Naphthenes are distributed between the extract and raffinate phases. Typical solvents for solvent extraction include phenol, furfural and N-methyl pyrrolidone. By controlling the solvent to
25 oil ratio, extraction temperature and method of contacting distillate to be extracted with solvent, one can control the degree of separation between the extract and raffinate phases.

HYDROTREATING

[0051] For hydrotreating, the catalysts are those effective for hydrotreating such as catalysts containing Group 6 metals (based on the IUPAC Periodic Table format having Groups from 1 to 18), Groups 8 - 10 metals, and mixtures thereof. Preferred metals include nickel, tungsten, molybdenum, cobalt and mixtures thereof. These metals or mixtures of metals are typically present as oxides or sulfides on refractory metal oxide supports. The mixture of metals may also be present as bulk metal catalysts wherein the amount of metal is 30 wt.% or greater, based on catalyst. Suitable metal oxide supports include oxides such as silica, alumina, silica-aluminas or titania, preferably alumina. Preferred aluminas are porous aluminas such as gamma or beta. The amount of metals, either individually or in mixtures, ranges from about 0.5 to 35 wt.%, based on the catalyst. In the case of preferred mixtures of groups 9-10 metals with group 6 metals, the groups 9-10 metals are present in amounts of from 0.5 to 5 wt.%, based on catalyst and the group 6 metals are present in amounts of from 5 to 30 wt.%. The amounts of metals may be measured by atomic absorption spectroscopy, inductively coupled plasma-atomic emission spectrometry or other methods specified by ASTM for individual metals.

[0052] The acidity of metal oxide supports can be controlled by adding promoters and/or dopants, or by controlling the nature of the metal oxide support, e.g., by controlling the amount of silica incorporated into a silica-alumina support. Examples of promoters and/or dopants include halogen, especially fluorine, phosphorus, boron, yttria, rare-earth oxides and magnesia. Promoters such as halogens generally increase the acidity of metal oxide supports while mildly basic dopants such as yttria or magnesia tend to decrease the acidity of such supports.

[0053] Hydrotreating conditions include temperatures of from 150 to 400°C, preferably 200 to 350°C, a hydrogen partial pressure of from 1480 to 20786 kPa (200 to 3000 psig), preferably 2859 to 13891 kPa (400 to 2000 psig), a space velocity of from 0.1 to 10 liquid hourly space velocity (LHSV), preferably 0.1 to 5 LHSV, and a hydrogen to feed ratio of from 89 to 1780 m³/m³ (500 to 28000 scf/B), preferably 178 to 890 m³/m³.

[0054] Hydrotreating reduces the amount of nitrogen- and sulfur-containing contaminants to levels which will not unacceptably affect the dewaxing catalyst in the subsequent dewaxing step. Also, there may be certain polynuclear aromatic species which will pass through the present mild hydrotreating step. These contaminants, if present, will be removed in a subsequent hydrofinishing step.

[0055] During hydrotreating, less than 5 wt.% of the feedstock, preferably less than 3 wt.%, more preferably less than 2 wt.%, is converted to 650°F (343°C) minus products to produce a hydrotreated feedstock whose VI increase is less than 4, preferably less than 3, more preferably less than 2 greater than the VI of the feedstock. The high wax contents of the present feeds results in minimal VI increase during the hydrotreating step.

[0056] The hydrotreated feedstock may be passed directly to the dewaxing step or preferably, stripped to remove gaseous contaminants such as hydrogen sulfide and ammonia prior to dewaxing. Stripping can be by conventional means such as flash drums or fractionators

DEWAXING CATALYST

[0057] The dewaxing catalyst may be either crystalline or amorphous.

Crystalline materials are molecular sieves that contain at least one 10 or 12 ring

5 channel and may be based on aluminosilicates (zeolites) or on silicoaluminophosphates (SAPOs). Zeolites used for oxygenate treatment may contain at least one 10 or 12 channel. Examples of such zeolites include ZSM-22, ZSM-23, ZSM-35, ZSM-48, ZSM-57, ferrierite, ITQ-13, MCM-68 and MCM-71. Examples of aluminophosphates containing at least one 10 ring
10 channel include ECR-42. Examples of molecular sieves containing 12 ring channels include zeolite beta, and MCM-68. The molecular sieves are described in US Patent Numbers 5,246,566, 5,282,958, 4,975,177, 4,397,827, 4,585,747, 5,075,269 and 4,440,871. MCM-68 is described in US Patent No. 6,310,265. MCM-71 and ITQ-13 are described in PCT published applications WO 0242207
15 and WO 0078677. ECR-42 is disclosed in US 6,303,534. Preferred catalysts include ZSM-48, ZSM-22 and ZSM-23. Especially preferred is ZSM-48. The molecular sieves are preferably in the hydrogen form. Reduction can occur in situ during the dewaxing step itself or can occur ex situ in another vessel.

20 [0058] Amorphous dewaxing catalysts include alumina, fluorided alumina, silica-alumina, fluorided silica-alumina and silica-alumina doped with Group 3 metals. Such catalysts are described for example in US Patent Nos. 4,900,707 and 6,383,366.

25 [0059] The dewaxing catalysts are bifunctional, i.e., they are loaded with a metal hydrogenation component, which is at least one Group 6 metal, at least one Group 8 - 10 metal, or mixtures thereof. Preferred metals are Groups 9 - 10 metals. Especially preferred are Groups 9 - 10 noble metals such as Pt, Pd or mixtures thereof (based on the IUPAC Periodic Table format having Groups

from 1 to 18). These metals are loaded at the rate of 0.1 to 30 wt.%, based on catalyst. Catalyst preparation and metal loading methods are described for example in US Patent No. 6,294,077, and include for example ion exchange and impregnation using decomposable metal salts. Metal dispersion techniques and catalyst particle size control are described in US Patent No. 5,282,958. Catalysts with small particle size and well dispersed metal are preferred.

[0060] The molecular sieves are typically composited with binder materials which are resistant to high temperatures which may be employed under dewaxing conditions to form a finished dewaxing catalyst or may be binderless (self bound). The binder materials are usually inorganic oxides such as silica, alumina, silica-aluminas, binary combinations of silicas with other metal oxides such as titania, magnesia, thoria, zirconia and the like and tertiary combinations of these oxides such as silica-alumina -thoria and silica-alumina magnesia. The amount of molecular sieve in the finished dewaxing catalyst is from 10 to 100, preferably 35 to 100 wt.%, based on catalyst. Such catalysts are formed by methods such spray drying, extrusion and the like. The dewaxing catalyst may be used in the sulfided or unsulfided form, and is preferably in the sulfided form.

[0061] Dewaxing conditions include temperatures of from 250 - 400°C, preferably 275 to 350°C, pressures of from 791 to 20786 kPa (100 to 3000 psig), preferably 1480 to 17339 kPa (200 to 2500 psig), liquid hourly space velocities of from 0.1 to 10 hr⁻¹, preferably 0.1 to 5 hr⁻¹ and hydrogen treat gas rates from 45 to 1780 m³/m³ (250 to 28000 scf/B), preferably 89 to 890 m³/m³ (500 to 5000 scf/B).

HYDROFINISHING

[0062] At least a portion of the product from dewaxing is passed directly to a hydrofinishing step without disengagement. It is preferred to hydrofinish the product resulting from dewaxing in order to adjust product qualities to desired specifications. Hydrofinishing is a form of mild hydrotreating directed to saturating any lube range olefins and residual aromatics as well as to removing any remaining heteroatoms and color bodies. The post dewaxing hydrofinishing is usually carried out in cascade with the dewaxing step. Generally the hydrofinishing will be carried out at temperatures from about 150°C to 350°C, preferably 180°C to 250°C. Total pressures are typically from 2859 to 20786 kPa (about 400 to 3000 psig). Liquid hourly space velocity is typically from 0. 1 to 5 LHSV (hr^{-1}), preferably 0. 5 to 3 hr^{-1} and hydrogen treat gas rates of from 44.5 to 1780 m^3/m^3 (250 to 10,000 scf/B).

[0063] Hydrofinishing catalysts are those containing Group 6 metals (based on the IUPAC Periodic Table format having Groups from 1 to 18), Groups 8 - 10 metals, and mixtures thereof. Preferred metals include at least one noble metal having a strong hydrogenation function, especially platinum, palladium and mixtures thereof. The mixture of metals may also be present as bulk metal catalysts wherein the amount of metal is 30 wt.% or greater based on catalyst. Suitable metal oxide supports include low acidic oxides such as silica, alumina, silica-aluminas or titania, preferably alumina. The preferred hydrofinishing catalysts for aromatics saturation will comprise at least one metal having relatively strong hydrogenation function on a porous support. Typical support materials include amorphous or crystalline oxide materials such as alumina, silica, and silica-alumina. The metal content of the catalyst is often as high as about 20 weight percent for non-noble metals. Noble metals are usually present in amounts no greater than about 1 wt.%.

[0064] The hydrofinishing catalyst is preferably a mesoporous material belonging to the M41S class or family of catalysts. The M41S family of catalysts are mesoporous materials having high silica contents whose preparation is further described in J. Amer. Chem. Soc., 1992, 114, 10834. Examples included MCM-41, MCM-48 and MCM-50. Mesoporous refers to catalysts having pore sizes from 15 to 100 Å. A preferred member of this class is MCM-41 whose preparation is described in US Patent No. 5,098,684. MCM-41 is an inorganic, porous, non-layered phase having a hexagonal arrangement of uniformly-sized pores. The physical structure of MCM-41 is like a bundle of straws wherein the opening of the straws (the cell diameter of the pores) ranges from 15 to 100 Angstroms. MCM-48 has a cubic symmetry and is described for example in US Patent No. 5,198,203 whereas MCM-50 has a lamellar structure. MCM-41 can be made with different size pore openings in the mesoporous range. The mesoporous materials may bear a metal hydrogenation component which is at least one of Group 8, Group 9 or Group 10 metals. Preferred are noble metals, especially Group 10 noble metals, most preferably Pt, Pd or mixtures thereof.

[0065] Generally the hydrofinishing will be carried out at temperatures from about 150°C to 350°C, preferably 180°C to 250°C. Total pressures are typically from 2859 to 20786 kPa (about 400 to 3000 psig). Liquid hourly space velocity is typically from 0. 1 to 5 LHSV (hr^{-1}), preferably 0. 5 to 3 hr^{-1} and hydrogen treat gas rates of from 44.5 to 1780 m^3/m^3 (250 to 10,000 scf/B).

[0066] In one embodiment, the present invention is directed to a lubricant comprising at least one base stock with a VI of at least 130 produced by a process which comprises:

- 5 (1) hydrotreating a feedstock having a wax content of at least about 60 wt.%, based on feedstock, with a hydrotreating catalyst under effective hydrotreating conditions such that less than 5 wt.% of the feedstock is converted to 650°F (343°C) minus products to produce a hydrotreated feedstock whose VI increase is less than 4 greater than the VI of the feedstock;
- 10 (2) stripping the hydrotreated feedstock to separate gaseous from liquid product; and
- 15 (3) hydrodewaxing the liquid product with a dewaxing catalyst which is at least one of ZSM-48, ZSM-57, ZSM-23, ZSM-22, ZSM-35, ferrierite, ECR-42, ITQ-13, MCM-71, MCM-68, beta, fluorided alumina, silica-alumina or fluorided silica alumina under catalytically effective hydrodewaxing conditions wherein the dewaxing catalyst contains at least one Group 9 or Group 10 noble metal.

15 **[0067]** Another embodiment of the present invention is directed to a lubricant comprising at least one base stock with a VI of at least 130 produced by a process which comprises:

- 20 (1) hydrotreating a lubricating oil feedstock having a wax content of at least about 50 wt.%, based on feedstock, with a hydrotreating catalyst under effective hydrotreating conditions such that less than 5 wt.% of the feedstock is converted to 650°F (343°C) minus products to produce a hydrotreated feedstock to produce a hydrotreated feedstock whose VI increase is less than 4 greater than the VI of the feedstock;
- 25 (2) stripping the hydrotreated feedstock to separate gaseous from liquid product;
- (3) hydrodewaxing the liquid product with a dewaxing catalyst which is at least one of ZSM-22, ZSM-23, ZSM-35, ferrierite, ZSM-48, ZSM-

57, ECR-42, ITQ-13, MCM-68, MCM-71, beta, fluorided alumina, silica-alumina or fluorided silica-alumina under catalytically effective hydrodewaxing conditions wherein the dewaxing catalyst contains at least one Group 9 or 10 noble metal; and

5 (4) hydrofinishing the product from step (3) with a mesoporous hydrofinishing catalyst from the M41S family under hydrofinishing conditions.

10 [0068] Another embodiment of the present invention is directed to a lubricant comprising at least one base stock with a VI of at least 130 produced by a process which comprises:

15 (1) hydrotreating a lubricating oil feedstock having a wax content of at least about 60 wt.%, based on feedstock, with a hydrotreating catalyst under effective hydrotreating conditions such that less than 5 wt.% of the feedstock is converted to 650°F (343°C) minus products to produce a hydrotreated feedstock to produce a hydrotreated feedstock whose VI increase is less than 4 greater than the VI of the feedstock;

20 (2) stripping the hydrotreated feedstock to separate gaseous from liquid product;

(3) hydrodewaxing the liquid product with a dewaxing catalyst which is ZSM-48 under catalytically effective hydrodewaxing conditions wherein the dewaxing catalyst contains at least one Group 9 or 10 noble metal; and

25 (a) Optionally, hydrofinishing the product from step (3) with MCM-41 under hydrofinishing conditions.

Additional details concerning the processes that make the current invention may be found in co-pending application USSN 60/416,865 which is hereby incorporated by reference in its entirety.

5 BASE STOCKS AND BASE OILS

[0069] A wide range of base stocks and base oils are known in the art. Base stocks and base oils that may be used as co-base stocks or co-base oils in combination with the base stocks and base oils of the present invention are 10 natural oils, mineral oils, and synthetic oils. These lubricant base stocks and base oils may be used individually or in any combination of mixtures with the instant invention. Natural, mineral, and synthetic oils (or mixtures thereof) may be used unrefined, refined, or rerefined (the latter is also known as reclaimed or reprocessed oil). Unrefined oils are those obtained directly from a natural, 15 mineral, or synthetic source and used without added purification. These include shale oil obtained directly from retorting operations, petroleum oil obtained directly from primary distillation, and ester oil obtained directly from an esterification process. Refined oils are similar to the oils discussed for unrefined oils except refined oils are subjected to one or more purification steps to improve 20 the at least one lubricating oil property. One skilled in the art is familiar with many purification processes. These processes include for example solvent extraction, distillation, secondary distillation, acid extraction, base extraction, filtration, percolation, dewaxing, hydroisomerization, hydrocracking, hydrofinishing, and others. Rerefined oils are obtained by processes analogous 25 to refined oils but using an oil that has been previously used.

[0070] Groups I, II, III, IV and V are broad categories of base oil stocks developed and defined by the American Petroleum Institute (API Publication 1509; www.API.org) to create guidelines for lubricant base stocks and base oils.

Group I base stock generally have a viscosity index of between about 80 to 120 and contains greater than about 0.03wt% sulfur and/or less than about 90% saturates. Group II base stocks generally have a viscosity index of between about 80 to 120, and contain less than or equal to about 0.03 wt% sulfur and greater than or equal to about 90% saturates. Group III stock generally has a viscosity index greater than about 120 and contain less than or equal to about 0.03 wt% sulfur and greater than about 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stock includes base stocks not included in Groups I-IV. The table below summarizes properties of each of these five Groups.

Table 1: API Classification of Base stocks and base oils

	<u>Saturates (wt%)</u>	<u>Sulfur (wt%)</u>	<u>Viscosity Index</u>
Group I	<90 &/or	>0.03% &	≥80 & <120
Group II	≥90 &	≤0.03% &	≥80 & <120
Group III	≥90 &	≤0.03% &	≥120
Group IV	Polyalphaolefins (PAO)		
Group V	All other base stocks and base oils not included in Groups I, II, III, or IV		

[0071] Base stocks and base oils may be derived from many sources. Natural oils include animal oils, vegetable oils (castor oil and lard oil, for example), and mineral oils. In regard to animal and vegetable oils, those possessing favorable thermal oxidative stability can be used. Of the natural oils, mineral oils are preferred. Mineral oils vary widely as to their crude source, for example, as to whether they are paraffinic, naphthenic, or mixed paraffinic-naphthenic. Oils

derived from coal or shale are also useful in the present invention. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrorefined, or solvent extracted.

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[0072] Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers, polymers or copolymer of hydrocarbyl-
10 substituted olefins where hydrocarbyl optionally contains O, N, or S, for example). Polyalphaolefin (PAO) oil base stocks are a commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C8, C10, C12, C14 olefins or mixtures thereof may be utilized. See U.S. Patents 4,956,122; 4,827,064; and 4,827,073, which are incorporated herein by reference in their
15 entirety.

[0073] Group III and PAO base stocks and base oils are typically available in a number of viscosity grades, for example, with kinematic viscosity at 100C of 4 cSt, 5cSt, 6cSt, 8cSt, 10cSt, 12cSt, 40cSt, 100cSt, and higher, as well as any
20 number of intermediate viscosity grades. In addition, PAO base stocks and base oils with high viscosity-index characteristics are available, typically in higher viscosity grades, for example, with kinematic viscosity at 100C of 100 cSt to 3000 cSt or higher. The number average molecular weights of the PAOs, which are known materials and generally available on a major commercial scale from
25 suppliers such as ExxonMobil Chemical Company, Chevron-Phillips, BP-Amoco, and others, typically vary from about 250 to about 3000. The PAOs are typically comprised of relatively low molecular weight hydrogenated polymers or oligomers of alphaolefins which include, but are not limited to, C2 to about C32 alphaolefins with C8 to about C16 alphaolefins, such as 1-octene, 1-decene,

1-dodecene and the like, being preferred. The preferred polyalphaolefins are poly-1-octene, poly-1-decene and poly-1-dodecene and mixtures thereof and mixed olefin-derived polyolefins. However, the dimers of higher olefins in the range of C14 to C18 may be used to provide low viscosity basestocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly trimers and tetramers of the starting olefins, with minor amounts of the higher oligomers, having a viscosity range of about 1.5 to 12 cSt. PAO base stocks and base oils may be used in formulated lubricant composition or functional fluids either individually or in any combination of two or more.

[0074] The PAO fluids may be conveniently made by the polymerization of an alphaolefin in the presence of a polymerization catalyst such as the Friedel-Crafts catalysts including, for example, aluminum trichloride, boron trifluoride or complexes of boron trifluoride with water, alcohols such as ethanol, propanol or butanol, carboxylic acids or esters such as ethyl acetate or ethyl propionate. For example the methods disclosed by U. S. Patent No. 4,149,178 or U.S. Patent No. 3,382,291 may be conveniently used herein. Other descriptions of PAO synthesis are found in the following U.S. Patent Nos. 3,742,082; 3,769,363; 3,876,720; 4,239,930; 4,367,352; 4,413,156; 4,434,408; 4,910,355; 4,956,122; and 5,068,487. The dimers of the C14 to C18 olefins are described in U.S. 4,218,330. All of the aforementioned patents are incorporated by reference herein in their entirety.

[0075] Other types of synthetic PAO base stocks and base oils include high viscosity index lubricant fluids as described in U.S. Patent Nos. 4,827,064 and 4,827,073, which can be highly advantageously used in combination with the base stocks and base oils of this inventions, as well as with in the formulated lubricant compositions or functions fluids of this same invention. Other useful

synthetic lubricating oils may also be utilized, for example, those described in the work "Synthetic Lubricants", Gunderson and hart, Reinhold Publ. Corp., New York, 1962, which is incorporated in its entirety.

5 [0076] Other synthetic base stocks and base oils include hydrocarbon oils that are derived from the oligomerization or polymerization of low-molecular weight compounds whose reactive group is not olefinic, into higher molecular weight compounds, which may be optionally reacted further or chemically modified in additional processes (e.g. isodewaxing, alkylation, esterification,
10 hydroisomerization, dewaxing, etc.) to give a base oil of lubricating viscosity.

[0077] Hydrocarbyl aromatic base stocks and base oils are also widely used in lubrication oils and functional fluids. In alkylated aromatic stocks (hydrocarbyl aromatics, for example), the alkyl substituents are typically alkyl groups of about 8 to 25 carbon atoms, usually from about 10 to 18 carbon atoms and up to three such substituents may be present, as described for the alkyl benzenes in ACS Petroleum Chemistry Preprint 1053-1058, "Poly n-Alkylbenzene Compounds: A Class of Thermally Stable and Wide Liquid Range Fluids", Eapen et al, Phila. 1984. Tri-alkyl benzenes may be produced by the
15 cyclodimerization of 1-alkynes of 8 to 12 carbon atoms as described in U.S. Patent No. 5,055,626. Other alkylbenzenes are described in European Patent Application No. 168534 and U.S. Patent No. 4,658,072. Alkylbenzenes are used as lubricant basestocks, especially for low-temperature applications (arctic vehicle service and refrigeration oils) and in papermaking oils. They are
20 commercially available from producers of linear alkylbenzenes (LABs) such as Vista Chem. Co, Huntsman Chemical Co., Chevron Chemical Co., and Nippon Oil Co. The linear alkylbenzenes typically have good low pour points and low temperature viscosities and VI values greater than 100 together with good
25 solvency for additives. Other alkylated aromatics which may be used when

desirable are described, for example, in "Synthetic Lubricants and High Performance Functional Fluids", Dressler, H., chap 5, (R. L. Shubkin (Ed.)), Marcel Dekker, N.Y. 1993. Aromatic base stocks and base oils may include, for example, hydrocarbyl alkylated derivatives of benzene, naphthalene, biphenyls, 5 di-aryl ethers, di-aryl sulfides, di-aryl sulfones, di-aryl sulfoxides, di-aryl methanes or ethanes or propanes or higher homologues, mono- or di- or tri-aryl heterocyclic compounds containing one or more O, N, S, or P.

[0078] The hydrocarbyl aromatics that can be used can be any hydrocarbyl 10 molecule that contains at least about 5% of its weight derived from an aromatic moiety such as a benzenoid moiety or naphthenoid moiety, or their derivatives. These hydrocarbyl aromatics include alkyl benzenes, alkyl naphthalenes, alkyl diphenyl oxides, alkyl naphthols, alkyl diphenyl sulfides, alkylated bis-phenol A, alkylated thiodiphenol, and the like. The aromatic can be mono-alkylated, 15 dialkylated, polyalkylated, and the like. The aromatic can be mono- or poly-functionalized. The hydrocarbyl groups can also be comprised of mixtures of alkyl groups, alkenyl groups, alkynyl, cycloalkyl groups, cycloalkenyl groups and other related hydrocarbyl groups. The hydrocarbyl groups can range from about C6 up to about C60 with a range of about C8 to about C40 often being 20 preferred. A mixture of hydrocarbyl groups is often preferred. The hydrocarbyl group can optionally contain sulfur, oxygen, and/or nitrogen containing substituents. The aromatic group can also be derived from natural (petroleum) sources, provided at least about 5% of the molecule is comprised of an above-type aromatic moiety. Viscosities at 100C of approximately 3 cSt to about 50 25 cSt are preferred, with viscosities of approximately 3.4 cSt to about 20 cSt often being more preferred for the hydrocarbyl aromatic component. In one embodiment, an alkyl naphthalene where the alkyl group is primarily comprised of 1-hexadecene is used. Other alkylates of aromatics can be advantageously used. Naphthalene, for example, can be alkylated with olefins such as octene,

decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like. Useful concentrations of hydrocarbyl aromatic in a lubricant oil composition can be about 2% to about 25%, preferably about 4% to about 20%, and more preferably about 4% to about 15%, depending on the application.

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[0079] Other useful lubricant oil base stocks include wax isomerate base stocks and base oils, comprising hydroisomerized waxy stocks (e.g. waxy stocks such as gas oils, slack waxes, fuels hydrocracker bottoms, etc.), hydroisomerized Fischer-Tropsch waxes, Gas-to-Liquids (GTL) base stocks and base oils, and 10 other wax isomerate hydroisomerized base stocks and base oils, or mixtures thereof. Fischer-Tropsch waxes, the high boiling point residues of Fischer-Tropsch synthesis, are highly paraffinic hydrocarbons with very low sulfur content. The hydroprocessing used for the production of such base stocks may use an amorphous hydrocracking/hydroisomerization catalyst, such as one of the 15 specialized lube hydrocracking (LHDC) catalysts or a crystalline hydrocracking/hydroisomerization catalyst, preferably a zeolitic catalyst. For example, one useful catalyst is ZSM-48 as described in U.S. Patent 5,075,269. Processes for making hydrocracked/hydroisomerized distillates and hydrocracked/hydroisomerized waxes are described, for example, in U.S. Patents 20 Nos. 2,817,693; 4,975,177; 4,921,594 and 4,897,178 as well as in British Patent Nos. 1,429,494; 1,350,257; 1,440,230 and 1,390,359. Particularly favorable processes are described in European Patent Application Nos. 464546 and 464547. Processes using Fischer-Tropsch wax feeds are described in US 4,594,172 and 4,943,672. Gas-to-Liquids (GTL) base stocks and base oils, 25 Fischer-Tropsch wax derived base stocks and base oils, and other wax isomerate hydroisomerized (wax isomerate) base stocks and base oils be advantageously used in the instant invention, and may have useful kinematic viscosities at 100C of about 3 cSt to about 50 cSt, preferably about 3 cSt to about 30 cSt, more preferably about 3.5 cSt to about 25 cSt, as exemplified by GTL4 with kinematic

viscosity of about 3.8 cSt at 100C and a viscosity index of about 138. These Gas-to-Liquids (GTL) base stocks and base oils, Fischer-Tropsch wax derived base stocks and base oils, and other wax isomerate hydroisomerized base stocks and base oils may have useful pour points of about -20C or lower, and under
5 some conditions may have advantageous pour points of about -25C or lower, with useful pour points of about -30C to about -40C or lower. Useful compositions of Gas-to-Liquids (GTL) base stocks and base oils, Fischer-Tropsch wax derived base stocks and base oils, and wax isomerate hydroisomerized base stocks and base oils are recited in U.S. Patent Nos.
10 6,080,301; 6,090,989, and 6,165,949 for example, and are incorporated herein in their entirety by reference.

[0080] Gas-to-Liquids (GTL) base stocks and base oils, Fischer-Tropsch wax derived base stocks and base oils, have a beneficial kinematic viscosity advantage over conventional Group II and Group III base stocks and base oils, which may be used as a co-base stock or co-base oil with the instant invention. Gas-to-Liquids (GTL) base stocks and base oils can have significantly higher kinematic viscosities, up to about 20-50 cSt at 100C, whereas by comparison commercial Group II base stocks and base oils can have kinematic viscosities,
15 up to about 15 cSt at 100C, and commercial Group III base stocks and base oils can have kinematic viscosities, up to about 10 cSt at 100C. The higher kinematic viscosity range of Gas-to-Liquids (GTL) base stocks and base oils, compared to the more limited kinematic viscosity range of Group II and Group III base stocks and base oils, in combination with the instant invention can provide additional beneficial advantages in formulating lubricant compositions.
20 Also, the exceptionally low sulfur content of Gas-to-Liquids (GTL) base stocks and base oils, and other wax isomerate hydroisomerized base stocks and base oils, in combination with the low sulfur content of suitable olefin oligomers and/or alkyl aromatics base stocks and base oils, and in combination with the
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instant invention can provide additional advantages in lubricant compositions where very low overall sulfur content can beneficially impact lubricant performance.

5 [0081] Alkylene oxide polymers and interpolymers and their derivatives containing modified terminal hydroxyl groups obtained by, for example, esterification or etherification are useful synthetic lubricating oils. By way of example, these oils may be obtained by polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers
10 (methyl-polyisopropylene glycol ether having an average molecular weight of about 1000, diphenyl ether of polyethylene glycol having a molecular weight of about 500-1000, and the diethyl ether of polypropylene glycol having a molecular weight of about 1000 to 1500, for example) or mono- and polycarboxylic esters thereof (the acidic acid esters, mixed C3-8 fatty acid esters, or the C13Oxo acid diester of tetraethylene glycol, for example).
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[0082] Esters comprise a useful base stock. Additive solvency and seal compatibility characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid, alkyl succinic acid, alkenyl succinic acid, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl
20 alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.
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[0083] Particularly useful synthetic esters are those which are obtained by reacting one or more polyhydric alcohols, preferably the hindered polyols (such as the neopentyl polyols e.g. neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol and dipentaerythritol) with alkanoic acids containing at least about 4 carbon atoms such as C5 to C30 acids (such as saturated straight chain fatty acids including caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, and behenic acid, or the corresponding branched chain fatty acids or unsaturated fatty acids such as oleic acid, or mixtures thereof).

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[0084] Suitable synthetic ester components include esters of trimethylol propane, trimethylol butane, trimethylol ethane, pentaerythritol and/or dipentaerythritol with one or more monocarboxylic acids containing from about 5 to about 10 carbon atoms. Such esters are widely available commercially, for 15 example, the Mobil P-41 and P-51 esters (ExxonMobil Chemical Company).

[0085] Other esters may included natural esters and their derivatives, fully esterified or partially esterified, optionally with free hydroxyl or carboxyl groups. Such ester may included glycerides, natural and/or modified vegetable 20 oils, derivatives of fatty acids or fatty alcohols.

[0086] Silicon-based oils are another class of useful synthetic lubricating oils. These oils include polyalkyl-, polyaryl-, polyalkoxy-, and polyaryloxy-siloxane oils and silicate oils. Examples of suitable silicon-based oils include tetraethyl 25 silicate, tetraisopropyl silicate, tetra-(2-ethylhexyl)silicate, tetra-(4-methylhexyl)silicate, tetra-(p-tert-butylphenyl) silicate, hexyl-(4-methyl-2-pentoxy) disiloxane, poly(methyl) siloxanes, and poly-(methyl-2-mehtylphenyl) siloxanes.

[0087] Another class of synthetic lubricating oil is esters of phosphorus-containing acids. These include, for example, tricresyl phosphate, trioctyl phosphate, diethyl ester of decanephosphonic acid.

- 5 [0088] Another type of base stocks and base oils includes polymeric tetrahydrofurans and the like, and their derivatives where reactive pendant or end groups are partially or fully derivatized or capped with suitable hydrocarbyl groups which may optionally contain O, N, or S.
- 10 [0089] The highly beneficial viscosity advantages of the novel base stocks and base oils described herein can be realized in combination with one or more performance additives, and with the desirable measured-to-theoretical viscosity ratios at less than -25C, preferably at -30C or lower, being realized in the resulting formulated lubricant compositions or functional fluids. These lubricant compositions or functional fluids also have the unique and highly desirable characteristic of a measured-to-theoretical viscosity ratio of 1.2 or lower, preferably 1.16 or lower, and in many instances more preferably 1.12 or lower. Thus the effect of the measured-to-theoretical viscosity feature of the novel base stocks and base oils described herein is preserved even in the presence of 15 performance additives, leading to improved formulated lubricant compositions or functional fluids comprising the novel base stocks and base oils described herein and one or more performance additives.
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PERFORMANCE ADDITIVES

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[0090] The instant invention can be used with additional lubricant components in effective amounts in lubricant compositions, such as for example polar and/or non-polar lubricant base oils, and performance additives such as for example, but not limited to, metallic and ashless oxidation inhibitors, metallic

and ashless dispersants, metallic and ashless detergents, corrosion and rust inhibitors, metal deactivators, anti-wear agents (metallic and non-metallic, low-ash, phosphorus-containing and non-phosphorus, sulfur-containing and non-sulfur types), extreme pressure additives (metallic and non-metallic, phosphorus-containing and non-phosphorus, sulfur-containing and non-sulfur types), anti-seizure agents, pour point depressants, wax modifiers, viscosity index improvers, viscosity modifiers, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, and others. For a review of many commonly used additives see Klamann in *Lubricants and Related Products*, Verlag Chemie, Deerfield Beach, FL; ISBN 0-89573-177-0, which also gives a good discussion of a number of the lubricant additives discussed mentioned below. Reference is also made "Lubricant Additives" by M. W. Ranney, published by Noyes Data Corporation of Parkridge, N.J. (1973). In particular, the base oils of this invention can show significant performance advantages with modern additives and/or additive systems, and additive packages that impart characteristics of low sulfur, low phosphorus, and/or low ash to formulated lubricant compositions or functional fluids.

20 ANITWEAR AND EXTREME PRESSURE ADDITIVES

[0091] Additional antiwear additives may be used with the present invention. While there are many different types of antiwear additives, for several decades the principal antiwear additive for internal combustion engine crankcase oils is a 25 metal alkylthiophosphate and more particularly a metal dialkyldithiophosphate in which the primary metal constituent is zinc, or zinc dialkyldithiophosphate (ZDDP). ZDDP compounds generally are of the formula $Zn[SP(S)(OR^1)(OR^2)]_2$ where R^1 and R^2 are C₁-C₁₈ alkyl groups, preferably C₂-C₁₂ alkyl groups. These alkyl groups may be straight chain or branched. For example, suitable alkyl

groups include isopropyl, 4-methyl-2-pentyl, and isoctyl. The ZDDP is typically used in amounts of from about 0.4wt% to about 1.4 wt. % of the total lube oil composition, although more or less can often be used advantageously.

- 5 [0092] However, it is found that the phosphorus from these additives has a deleterious effect on the catalyst in catalytic converters and also on oxygen sensors in automobiles. One way to minimize this effect is to replace some or all of the ZDDP with phosphorus-free antiwear additives.
- 10 [0093] A variety of non-phosphorus additives are also used as antiwear additives. Sulfurized olefins are useful as antiwear and EP additives. Sulfur-containing olefins can be prepared by sulfurization of various organic materials including aliphatic, arylaliphatic or alicyclic olefinic hydrocarbons containing from about 3 to 30 carbon atoms, preferably 3-20 carbon atoms. The olefinic
15 compounds contain at least one non-aromatic double bond. Such compounds are defined by the formula $R^3R^4C=CR^5R^6$ where each of R^3-R^6 are independently hydrogen or a hydrocarbon radical. Preferred hydrocarbon radicals are alkyl or alkenyl radicals. Any two of R^3-R^6 may be connected so as to form a cyclic ring. Additional information concerning sulfurized olefins and their preparation
20 can be found in U.S. Patent No. 4,941,984, incorporated by reference herein in its entirety.

- [0094] The use of polysulfides of thiophosphorus acids and thiophosphorus acid esters as lubricant additives is disclosed in U.S. Patent Nos. 2,443,264; 2,471,115; 2,526,497; and 2,591,577. Addition of phosphorothionyl disulfides as an antiwear, antioxidant, and EP additives is disclosed in U.S. Patent No. 3,770,854. Use of alkylthiocarbamoyl compounds (bis(dibutyl)thiocarbamoyl, for example) in combination with a molybdenum compound (oxymolybdenum diisopropylphosphorodithioate sulfide, for example) and a phosphorus ester

(dibutyl hydrogen phosphite, for example) as antiwear additives in lubricants is disclosed in U.S. Patent No. 4,501,678. U.S. Patent No. 4,758,362 discloses use of a carbamate additive to provide improved antiwear and extreme pressure properties. The use of thiocarbamate as an antiwear additive is disclosed in U.S. Patent No. 5,693,598. Thiocarbamate/molybdenum complexes such as moly-sulfur alkyl dithiocarbamate trimer complex ($R=C_8-C_{18}$ alkyl) are also useful antiwear agents. Each of the above mentioned patents is incorporated by reference herein in its entirety.

10 [0095] Esters of glycerol may be used as antiwear agents. For example, mono-, di, and tri-oleates, mono-palmitates and mono-myristates may be used.

15 [0096] ZDDP is combined with other compositions that provide antiwear properties. U.S. Patent No. 5,034,141 discloses that a combination of a thiodixanthogen compound (octylthiodixanthogen, for example) and a metal thiophosphate (ZDDP, for example) can improve antiwear properties. U.S. Patent No. 5,034,142 discloses that use of a metal alkoxyalkylxanthate (nickel ethoxyethylxanthate, for example) and a dixanthogen (diethoxyethyl dixanthogen, for example) in combination with ZDDP improves antiwear properties.

20

[0097] Antiwear additives may be used in an amount of about 0.01 to 6 weight percent, preferably about 0.01 to 4 weight percent.

25 VISCOSITY INDEX IMPROVERS

[0098] Viscosity index improvers (also known as VI improvers, viscosity modifiers, or viscosity improvers) provide lubricants with high- and low-

temperature operability. These additives impart shear stability at elevated temperatures and acceptable viscosity at low temperatures.

[0099] Suitable viscosity index improvers include both low molecular weight and high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. Typical molecular weights of these polymers are between about 10,000 to 1,000,000, more typically about 20,000 to 500,000, and even more typically between about 50,000 and 200,000.

10

[00100] Examples of suitable viscosity index improvers are polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity index improver. Another suitable viscosity index improver is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity index improvers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of about 50,000 to 200,000 molecular weight.

[00101] Viscosity index improvers may be used in an amount of about 0.01 to 15 weight percent, preferably about 0.01 to 10 weight percent, and in some instances, more preferably about 0.01 to 5 weight percent.

25

ANTIOXIDANTS

[00102] Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence

of sludge, or a viscosity increase in the lubricant. One skilled in the art knows a wide variety of oxidation inhibitors that are useful in lubricating oil compositions. See, Klamann in *Lubricants and Related Products, op cite*, and U.S. Patent Nos. 4,798,684 and 5,084,197, for example, the disclosures of which are incorporated by reference herein in their entirety. Useful antioxidants include hindered phenols. These phenolic antioxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. Typical phenolic antioxidant compounds are the hindered phenolics which are the ones which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with C₆+ alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; and 2-methyl-6-t-butyl-4-dodecyl phenol. Other useful hindered mono-phenolic antioxidants may include for example hindered 2,6-di-alkyl-phenolic proprionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used in combination with the instant invention. Examples of ortho coupled phenols include: 2,2'-bis(6-t-butyl-4-heptyl phenol); 2,2'-bis(6-t-butyl-4-octyl phenol); and 2,2'-bis(6-t-butyl-4-dodecyl phenol). Para coupled bis phenols include for example 4,4'-bis(2,6-di-t-butyl phenol) and 4,4'-methylene-bis(2,6-di-t-butyl phenol).

[00103] Non-phenolic oxidation inhibitors which may be used include aromatic amine antioxidants and these may be used either as such or in combination with phenolics. Typical examples of non-phenolic antioxidants include: alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula R⁸R⁹R¹⁰N where R⁸ is an aliphatic, aromatic or

substituted aromatic group, R⁹ is an aromatic or a substituted aromatic group, and R¹⁰ is H, alkyl, aryl or R¹¹S(O)_xR¹² where R¹¹ is an alkylene, alkenylene, or aralkylene group, R¹² is a higher alkyl group, or an alkenyl, aryl, or alkaryl group , and x is 0, 1 or 2. The aliphatic group R⁸ may contain from 1 to about 20
5 carbon atoms, and preferably contains from 6 to 12 carbon atoms. The aliphatic group is a saturated aliphatic group. Preferably, both R⁸ and R⁹ are aromatic or substituted aromatic groups, and the aromatic group may be a fused ring aromatic group such as naphthyl. Aromatic groups R⁸ and R⁹ may be joined together with other groups such as S.

10

[00104] Typical aromatic amines antioxidants have alkyl substituent groups of at least about 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than about 14 carbon atoms. The general types of amine antioxidants
15 useful in the present compositions include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more aromatic amines are also useful. Polymeric amine antioxidants can also be used. Particular examples of aromatic amine antioxidants useful in the present invention include: p,p'-dioctyldiphenylamine;
20 t-octylphenyl-alpha-naphthylamine; phenyl-alphanaphthylamine; and p-octylphenyl-alpha-naphthylamine.

[00105] Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants. Low sulfur peroxide decomposers are useful as
25 antioxidants.

[00106] Another class of antioxidant used in lubricating oil compositions is oil-soluble copper compounds. Any oil-soluble suitable copper compound may be blended into the lubricating oil. Examples of suitable copper antioxidants

include copper dihydrocarbyl thio or dithio-phosphates and copper salts of carboxylic acid (naturally occurring or synthetic). Other suitable copper salts include copper dithiacarbamates, sulphonates, phenates, and acetylacetones. Basic, neutral, or acidic copper Cu(I) and or Cu(II) salts derived from alkenyl succinic acids or anhydrides are known to be particularly useful.

[00107] Preferred antioxidants include hindered phenols, arylamines, low sulfur peroxide decomposers and other related components. These antioxidants may be used individually by type or in combination with one another. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 2 weight percent.

FRICTION MODIFIERS

[00108] A friction modifier is any material or materials that can alter the coefficient of friction of any lubricant or fluid containing such material(s). Friction modifiers, also known as friction reducers, or lubricity agents or oiliness agents, and other such agents that change the coefficient of friction of lubricant base oils, formulated lubricant compositions, or functional fluids, may be effectively used in combination with the base oils or lubricant compositions of the present invention if desired. Friction modifiers that lower the coefficient of friction are particularly advantageous in combination with the base oils and lube compositions of this invention. Friction modifiers may include metal-containing compounds or materials as well as ashless compounds or materials, or mixtures thereof. Metal-containing friction modifiers may include metal salts or metal-ligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have low-ash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivative of alcohols, polyols,

glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles, triazoles, and other polar molecular functional groups containing effective amounts of O, N, S, or P, individually or in combination. In particular, Mo-containing compounds can be particularly effective such as for example Mo-dithiocarbamates, Mo(DTC), Mo-dithiophosphates, Mo(DTP), Mo-amines, Mo (Am), Mo-alcoholates, Mo-alcohol-amides, etc.

10 [00109] Ashless friction modifiers may have also include lubricant materials that contain effective amounts of polar groups, for example hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hyrdocarbyl groups containing effective amounts of O, N, S, or P, individually or in combination.

15 Other friction modifiers that may be particularly effective include, for example, salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long-chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, and the like. In some instances fatty organic acids, fatty amines, and sulfurized fatty acids may be used as suitable friction modifiers.

20

[00110] Useful concentrations of friction modifiers may range from about 0.01 wt% to 10-15 wt% or more, often with a preferred range of about 0.1 wt% to 5 wt%. Concentrations of molybdenum containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from about 10 ppm to 3000 ppm or more, and often with a preferred range of about 20-2000 ppm, and in some instances a more preferred range of about 30-1000 ppm. Friction modifiers of all types may be used alone or in mixtures with the materials of this invention. Often mixtures of two or more friction

modifiers, or mixtures of friction modifiers(s) with alternate surface active material(s), are also desirable.

POUR POINT DEPRESSANTS

5

[00111] Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present invention if desired. These pour point depressants may be added to lubricating compositions of the present invention to lower the minimum temperature at which the fluid will flow
10 or can be poured. Examples of suitable pour point depressants include polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. U.S. Patent Nos. 1,815,022; 2,015,748; 2,191,498; 2,387,501; 2,655, 479;
15 2,666,746; 2,721,877; 2,721,878; and 3,250,715 describe useful pour point depressants and/or the preparation thereof. Each of these references is incorporated herein in its entirety. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent.

CORROSION INHIBITORS

[00112] Corrosion inhibitors are used to reduce the degradation of metallic parts that are in contact with the lubricating oil composition. Suitable corrosion inhibitors include thiadizoles. See, for example, U.S. Patent Nos. 2,719,125;
25 2,719,126; and 3,087,932, which are incorporated herein by reference in their entirety. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent.

SEAL COMPATIBILITY ADDITIVES

[00113] Seal compatibility agents help to swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Suitable seal
5 compatibility agents for lubricating oils include organic phosphates, aromatic esters, aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride. Additives of this type are commercially available. Such additives may be used in an amount of about 0.01 to 3 weight percent, preferably about 0.01 to 2 weight percent.

10

ANTI-FOAM AGENTS

[00114] Anti-foam agents may advantageously be added to lubricant compositions. These agents retard the formation of stable foams. Silicones and
15 organic polymers are typical anti-foam agents. For example, polysiloxanes, such as silicon oil or polydimethyl siloxane, provide antifoam properties. Anti-foam agents are commercially available and may be used in conventional minor amounts along with other additives such as demulsifiers; usually the amount of these additives combined is less than 1 percent and often less than 0.1 percent.

20

INHIBITORS AND ANTIRUST ADDITIVES

[00115] Antirust additives (or corrosion inhibitors) are additives that protect lubricated metal surfaces against chemical attack by water or other
25 contaminants. A wide variety of these are commercially available; they are referred to also in Klamann, *op. cit.*

[00116] One type of antirust additive is a polar compound that wets the metal surface preferentially, protecting it with a film of oil. Another type of antirust

additive absorbs water by incorporating it in a water-in-oil emulsion so that only the oil touches the metal surface. Yet another type of antirust additive chemically adheres to the metal to produce a non-reactive surface. Examples of suitable additives include zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines. Such additives may be used in an amount of about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent. Additional types of additives may be further incorporated into lubricant compositions or functional fluids of this invention, and may include one or more additives such as, for example, demulsifiers, solubilizers, fluidity agents, coloring agents, chromophoric agents, and the like, as required. Further, each additive type may include individual additives or mixtures of additive.

TYPICAL ADDITIVE AMOUNTS

- 15 [00117] When lubricant compositions contain one or more of the additives discussed above, the additive(s) are blended into the composition in an amount sufficient for it to perform its intended function. Typical amounts of such additives useful in the present invention are shown in the Table 2 below.
- 20 [00118] Note that many additives, additive concentrates, and additive packages that are purchased from manufacturers may incorporate a certain amount of base oil solvent, or diluent, in the formulation. Accordingly, the weight amounts in Table 3 below are directed to the amount of active ingredient (that is the non-solvent portion of the ingredient). The weight percents indicated below are 25 based on the total weight of the lubricating oil composition. In practical applications, however, additive components, additive concentrates, and additive packages are used as purchased from manufactures, and may include certain amounts of base oil solvent or diluent. The additive and formulation components as recited in the Examples and Comparative Examples below are

used "as is" from their manufacturers or suppliers, unless specifically noted otherwise.

Table 2. Typical Amounts of Various Lubricant Oil Components

5

Compound	Approximate Weight Percent (Useful)	Approximate Weight Percent (Preferred)
Viscosity Index Improver	0-40	0.01-30, more preferably 0.01 to 15
Antioxidant	0.01-5	0.01-2
Corrosion Inhibitor	0.01-5	0.01-1.5
Anti-wear Additive	0.01-6	0.01-4
Pour Point Depressant	0-5	0.01-1.5
Demulsifier	0.001-3	0.001-1.5
Anti-foam Agent	0.001-3	0.001-0.15
Base Oil(s)	Balance	Balance

EXAMPLES

Example 1

[00119] By controlling other non-inventive process parameters well known to those skilled in the art, the inventive base stocks and base oils as described by the inventive process herein can be made over a range of low to high viscosity oils as is typical in the industry thus allowing for blending of base stocks with a final viscosity between those two end points. In this example, the base stocks were manufactured using the inventive method to a higher viscosity level of 6.6 cSt and a lower viscosity level of 4.0 cSt. For this example, as may be seen in table 4, the Inventive Oil A was derived from a mineral oil wax feedstock to the

process described herein and then blended to two viscometric targets: 4.0 cSt and 5.7 cSt. Similarly, the Inventive Oil B for this example was derived from a Fischer-Tropsch wax, blended to final viscosity targets of 4.0 cSt and 6.3 cSt. The Comparative Oils for this example are commercially available base stocks
5 blended to viscometric targets of 4 cSt, 5 cSt and 8 cSt.

[00120] Viscometric properties of Inventive base oils A and B and the Comparative Base Oil 1 at comparable viscosity indices are shown below (Table 3). The Kinematic Viscosities were measured by ASTM method D445. The
10 measured CCS viscosity were found by using ASTM method D5293. The Theoretical Viscosity were calculated per the Walther/MacCoull Equation as found in ASTM D341 (Appendix 1).

[00121] The ratio between measured and theoretical viscosity (i.e.
15 ratio=measured/theoretical) at -30C or below is less than 1.2 for the Inventive Base Oils, but is higher than 1.2 for the Comparative Base Oils at the same temperatures.

Table 3: Base Stocks and Properties

	<u>Inventive Base Oil</u>				<u>Comparative Base Oil</u>		
	Oil A 4 cSt	Oil A 5.7 cSt	Oil B 4 cSt	Oil B 6.3 cSt	Comp.O il 1 4 cSt	Comp.Oil 1 5 cSt	Comp.O il 1 8 cSt
Viscosity Index	142	150	143	153	142	146	146
<u>Kinematic Viscosity, ASTM D445</u>							
at 100C, cSt	4	5.7	3.8	6.30	4.0	5.1	8.0
at 40C, cSt	16.8	28.4	15.3	31.8	16.5	24.1	46.3
<u>CCS Viscosity (Measured), ASTM D5293</u>							
at -30C, cP	TLTM	2506	680	2630	1160	2270	8000
at -35C, cP	1354	4499	1140	4670	2440	4620	THTM
<u>Theoretical Viscosity (Walther/MacCoull Eq.)</u>							
at -30C, cP	894	2439	722	2806	866	1877	6056
at -35C, cP	1515	4364	1206	5019	1466	3329	11 340
<u>Viscosity Ratio, measured/theoretical</u>							
at -30C, cP	-	1.03	0.94	0.94	1.34	1.21	1.32
at -35C, cP	0.89	1.03	0.94	0.93	1.66	1.39	-

(TLTM = too low to measure)

(THTM = too high to measure)

[00122] It has similarly being observed that the novel base stocks recited herein have a much lower scanning-Brookfield viscosity (ASTM D5133) values at low temperature (below -20C). Scanning Brookfield viscosity measurements are performed at much lower shear rates, and slower cooling rates than the D5293 CCS technique. In the particular example illustrate in table 4, the

inventive base stocks ratios of (measured / theoretically predicted) viscosity ranges between 2.5 (@-20C) and 7 (@-35C), while the comparable commercially available base stock, with similar viscosity and VI, has a ratio ranging between 11 (@-20C), and 63 (@-25C), and its viscosity is too high to
5 be measured below -25C.

[00123] The viscosity-temperature performance for the Comparative Base Oil and the Inventive Base Oil are also demonstrably different over a range of base oil viscosity, as measured by kinematic viscosity at 100C. At comparable
10 kinematic viscosity at 100C , it is evident that the Inventive Base Oil has superior (i.e. lower) low-temperature viscosity than that of comparative base oil 1, at temperatures such as, for example, -30C and -35C (Table 4 and Figure 2).

Table 4: Base Oil CCS Low-Temperature Viscosity at Comparable Kinematic Viscosity

KV @ 100C, cSt	Inventive Base Oil A		Comparative Base Oil 1	
	4-6.6 cSt Mixtures	4-8 cSt Mixtures	4-6.6 cSt Mixtures	4-8 cSt Mixtures
KV @ 100C, cSt	CCS @ - 30C cP	CCS @ - 35C cP	CCS @ - 30C cP	CCS @ - 35C cP
4.0	857	1445	1524	2798
4.6	1282	2214	2032	3713
6.0	2830	5120	3600	6700

15 Example 2

[00124] In this example (Table 5), the inventive functional fluid is that of a hydraulic oil. The performance additive package A is suitable for use in hydraulic oil compositions. However, these examples do not limit the possible

alternate lubricant compositions that may be suitably used in this invention. These examples are formulated to meet the same viscosity target of ISO 32 (viscosity grade according to ISO 3448, as published by the International Standards Organization), which is one of many typical viscosity grades of
5 hydraulic oils.

[00125] Surprisingly, Inventive Example 1, formulated exclusively with the inventive base oil A of Example 1 and with no viscosity modifier, demonstrates excellent Brookfield viscosity at -20F of 3010 cP. This performance is
10 significantly better (i.e. lower) than that of comparative example CE.3 (a commercially available composition, with mixed paraffinic/naphthenic-type mineral oils and viscosity modifier) and is dramatically better (i.e lower) than that of comparative example CE.1 (formulated with only Group III comparative base oil Comp.Oil 1 and no viscosity modifier).

15

[00126] Similarly, Inventive Example 2, formulated with the inventive base oil A Example 1 and viscosity modifier, demonstrates excellent Brookfield viscosity at -20F of 2150 cP. This performance is significantly better (i.e. lower) than that of the other viscosity modified comparative examples CE.1 (formulated with
20 Group III comparative base oil Comp.Oil 1 and viscosity modifier) and CE.3 (a commercially available composition, with mixed paraffinic/naphthenic-type mineral oils and viscosity modifier).

Table 5. Inventive and Comparative Examples

	Inventive Examples		Comparative Examples		
	1	2	CE.1	CE.2	CE.3
Formulated Lubricant Composition (wt%)					
Inventive Base Oil A , 4 cSt	12.64	45.625			
Inventive Base Oil A , 6 cSt	84.61	45.625			
Comparative Base Oil 1, 5 cSt			56.41	91.25	
Comparative Base Oil 1, 8 cSt			40.84		
Mineral Oil, 150 SPN					55.5
Mineral Oil, 600 SPN					6.43
Mineral Oil, 65 SNN					29.32
Pour Point depressant	0.1	0.1	0.1	0.1	0.1
Viscosity Modifier (Polymethacrylate)		6		6	6
Hydraulic Additive Package A	2.65	2.65	2.65	2.65	2.65
Properties					
Kinematic Viscosity at 40C, cSt (D445)	32.7	32.4	32.8	32.4	32
Kinematic Viscosity at 100C, cSt (D445)	6.4	7.1	6.3	7.0	6.1
Viscosity Index (D2270)	149	190	148	186	142
Pour Point, C (D97)	-39	-51	-30	-42	- 40
Brookfield Viscosity at -20F, cP (D2983)	3010	2150	137800	3960	4940

(SPN = Solvent Paraffinic Neutral)

(SNN = Solvent Naphthenic Neutral)

- 5 These examples demonstrate a surprising and unexpected advantage of the novel base stocks recited herein versus other Group III base stocks in an application where low-temperature viscosity is an essential contributor to overall good wide-temperature performance.